

Attorney Docket No. 02860.0757

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

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In re Application of:)
 Shigeru HOSOE) Group Art Unit: 1731
Serial No.: 10/721,547) Examiner:
Filed: November 26, 2003) Mr. Seam E Vincent
For:)
PROCESSING METHOD OF FORMING)
A TRANSFERRING SURFACE,)
PROCESSING MACHINE, DIE FOR)
OPTICAL ELEMENT AND A DIAMOND)
TOOL)
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Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

DECLARATION UNDER 37 C.F.R. 1.132

Sir:

1. I, Shigeru HOSOE hereby declare and state as follows:

That I have been awarded a Doctrate in industrial science and technology from Tokyo University of Science in March 1995. Since April 1980, I have been employed by Konica Corporation, the Assignee of the above identified application. During my employment, I have been engaged in the research and development center in the field of Optics.

That I am the sole inventor of the present invention and am familiar with the subject matter of the present invention. I have read and understood the Office Action dated 03/10/2009.

2. What follows is an accurate summary of comparative tests conducted in accordance with my instruction under my supervision.

3. The subject matter of the present invention recited in amended claim 1 is a method of forming a die surface onto a producing die to produce an optical element, wherein the die surface transfers an optical surface onto the produced optical element, the method comprising the steps of:

bringing a cutting tool to come in contact with a material so as to cut the material; and

moving the material relatively to the cutting tool so as to form the die surface having a diameter of 5 mm or less with a curvature on the material;

wherein the material is one of a ceramic and a tungsten carbide cobalt alloy and has a hardness not smaller than Rockwell hardness HRA 80 or Vickers hardness Hv 1000 and the cutting step is conducted to cut the material with a cutting-in depth of 1 μ m or less, and

wherein the cutting tool has a cutting edge capable of coming in contact with the material, the cutting edge comprises a diamond and the cutting step is conducted while the cutting tool is set such that a single point of the cutting edge comes in contact with the material as a cutting point, the cutting point of the cutting edge is fixed at the single point, and a (110) surface of the diamond is used as a rake face of the cutting point.

Conventionally, a process to form a die surface of a die on a super hard material having a hardness not smaller than Rockwell hardness HRA 80 or Vickers hardness Hv 1000 has been conducted by a grinding process. However, recently, since a die surface is required to transfer a curved optical surface with a diameter of 5 mm or less, it becomes difficult for the grinding process to form such a small curved die surface on the above super hard material with high accuracy.

Then, the cutting process recited in amended claim 1 has been devised to make it possible to form such a small curved die surface on the above super hard material with high accuracy.

The present invention is rejected under 35 USC 103(a) as being unpatentable over Uno et al (US 25,008,002) in view of Roffman et al (US 5,861,114) and Oomen (US 5,078,551).

Uno teaches to conduct a grinding process and a polishing process on a base mold and an ion plating process on the polished base mold. However, Uno teaches nothing about a technique to conduct a cutting process to form a die surface on the above super hard material.

Roffman discloses a cutting process to form a die surface on a stainless steel with a single point diamond lathe, and further discloses a die surface to transfer a curved optical lens. However, Roffman teaches nothing about a cutting technique such as a cutting-in depth, a rake face and the like, and also Roffman teaches nothing

about a cutting technique form a die surface on the above super hard material.

Oomen discloses a cutting process to cut a flat plate having a Vickers hardness of 86 Hv or less with a diamond cutting edge. However, Oomen teaches a cutting technique to use a (001)-crystal face of the diamond as a rake face with a cutting-in depth of 5 μm . This cutting technique of Oomen is quite different from the cutting technique of the present invention to use a (110)-crystal face of the diamond as a rake face with a cutting-in depth of 1 μm or less.

Therefore, none of Uno, Roffman and Oomen teaches about a cutting technique to form a die surface on the above super hard material.

Further, none of the above references teaches a cutting technique to use a (110)-crystal face of the diamond as a rake face with a cutting-in depth of 1 μm or less in order to form a small curved die surface on the above super hard material.

Then, in order to verify the effect of the cutting technique of the present invention as being unexpected from the above references, the following comparative tests were conducted in accordance with my instruction under my supervision.

4. Cutting test

4-1. Example 1

Firstly, a portion of a die body made of a sintered metal of silicon carbide was roughly cut into a curved basic surface to transfer an optical surface shown in Fig. 1 by a grinding process. Then, a ceramic layer of silicon carbide with a thickness of 500 μm was formed on the curved basic surface by a CVD process so that a super hard foundation surface with a hardness of 2400 HV was formed on the curved basic surface.

Next, the super hard foundation surface on the curved basic surface was subjected to a grinding process by a high accuracy grinding machine having an axial resolving power of about 100 nm and equipped with a grinding stone on which diamond abrasive grains were deposited by a nickel electrodeposition process. As a result, the super hard foundation surface was shaped into a rough die surface capable of transferring an aspheric optical surface expressed by numerical factors shown in Table 1 with a shape accuracy of about 1 μm .

Table 1

Optical effective diameter	ϕ 3.0 mm
Depth	Concave 1.62 mm
Center R	1.22121

Conical constant k	-0.682735
Term A4	0.175154×10^{-1}
Term A6	0.240932×10^{-2}
Term A8	0.204531×10^{-2}
Term A10	0.653289×10^{-3}
Term A12	-0.48930×10^{-3}
Term A14	-0.827296×10^{-4}
Term A16	0.149693×10^{-3}
Term A18	0.330066×10^{-4}
Term A20	-0.275518×10^{-4}

Subsequently, the above rough die surface was subjected to a cutting process by a high rigidity hyper precision 3-axis lathe shown in Fig. 2 which had an axis

resolving power of 1 nm, a main axis rigidity of 1000 N/ μ m, a slide table rigidity of 1000 N/ μ m, a B axis radial rigidity of 300 N/ μ m, and a B axis turning angle accuracy of 0.01 sec. In the 3-axis lathe, the die body was attached to a main shaft and a diamond cutting tool was set in such a way that a (110)-crystal face of the diamond was used as a rake face, another (110)-crystal face of the diamond locating on an extension line in a direction crossing the rake face was used as a flank face, a rake angle was 0°, and a relief angle was 5°. With the above arrangement on the lathe, the cutting process was conducted for 10 minutes per one time in such a way that the rough die surface was shifted relatively to the rake face along the flank face with a cutting-in depth of 100 nm, a feed rate of 0.2 mm/min and a main shaft rotation of 1000 rpm. As a result, after the cutting process was conducted 10 times for the rough die surface, the rough surface on the rough die surface formed by the grinding process was removed by the cutting process, whereby the die surface was made to a smooth surface. At this stage, the shape of the die surface was measured, and shape errors between the measured shape and an ideal shape were obtained.

Then, a correcting process was conducted by the use of the same cutting edge of the same cutting tool as that in the above cutting process in such a way that the cutting depth was increased or decreased continuously depending on a position on the die surface so as to correct the above shape errors. After this correcting process, the shape error and the surface roughness of

the die surface were measured, and the measurement results are indicated in Table 2.

4-2. Example 2

The grinding process, the cutting process and the correcting process were conducted in the same way as that in Example 1 except that a (100)-crystal face of the diamond was used as a flank face in place of the (110)-crystal face. After the correcting process, the shape error and the surface roughness of the die surface were measured, and the measurement results are indicated in Table 2.

4-3. Comparative Example 1

The grinding process, the cutting process and the correcting process were conducted in the same way as that in Example 1 except that in accordance with the teaching of Oomen, a (100)-crystal face of the diamond equivalent to the (001)-crystal face taught by Oomen was used as a rake face, another (100)-crystal face of the diamond locating on an extension line in a direction crossing the rake face was used as a flank face. After the correcting process, the shape error and the surface roughness of the die surface were measured, and the measurement results are indicated in Table 2.

4-4. Comparative Example 2

The grinding process, the cutting process and the correcting process were conducted in the same way as

that in Example 1 except that in accordance with the teaching of Oomen, a (100)-crystal face of the diamond was used as a rake face, a (110)-crystal face of the diamond locating on an extension line in a direction crossing the rake face was used as a flank face. After the correcting process, the shape error and the surface roughness of the die surface were measured, and the measurement results are indicated in Table 2.

4-5. Comparative Example 3

The grinding process, the cutting process and the correcting process were conducted in the same way as that in Example 1 except that a (111)-crystal face of the diamond was used as a rake face, another (111)-crystal face of the diamond locating on an extension line in a direction crossing the rake face was used as a flank face. After the correcting process, the shape error and the surface roughness of the die surface were measured, and the measurement results are indicated in Table 2.

4-6. Comparative Example 4

The grinding process, the cutting process and the correcting process were conducted in the same way as that in Example 1 except that in accordance with the teaching of Oomen, the cutting-in depth was made to 5 μm in place of 100 nm. After the correcting process, the shape error and the surface roughness of the die surface were measured, and the measurement results are indicated in Table 2.

5. Measurement results and remarks

Table 2

	Shape error (nmpV)	Surface roughness (Rz: nm)
Example 1	43	12.8
Example 2	84.5	26.3
Comparative example 1	218	53.2
Comparative example 2	234	62.5
Comparative example 3	425	123.5
Comparative example 4	765	564.8

6. Evaluation

6-1. Shape error

According to Marechal criterion, the shape error SE of an idealized lens is required to satisfy the following formula:

$$SE < \lambda/4,$$

where λ represents a wavelength of a light flux.

Therefore, since a visible wavelength range is 400 to 700 nm, the shape error SE of an optical element is required to be less than 100 nm (400/4) in order to cover the entire visible wavelength range.

Accordingly, the shape error is usually evaluated as follows.

Shape error (nmpV)	Evaluation
50 or less	Good
51 to 100	Not bad (Acceptable)

101 or more

Bad

From the above criteria, Example 1 was classified into "good", Example 2 was classified into "not bad", and Comparative examples 1 to 4 were classified into "bad".

6-2. Surface roughness

When an optical surface is a rough surface, the scattering of light takes place on the rough surface. As a result, various problems such as the deterioration of contrast, the reduction of light amount and the like take place in the optical function.

Accordingly, the surface roughness is usually evaluated as follows.

Surface roughness (Rz: nm)	Evaluation
20 or less	Good
21 to 40	Not bad (Acceptable)
41 or more	Bad

From the above criteria, Example 1 was classified into "good", Example 2 was classified into "not bad", and Comparative examples 1 to 4 were classified into "bad".

7. Conclusion

As can be seen from the results in Examples 1 and 2, with the cutting technique of the present invention to use a (110)-crystal face of the diamond as a rake face

with a cutting-in depth of 1 μm or less, a die surface to transfer an optical surface can be formed efficiently with a high accuracy on a super hard material having a hardness not smaller than Rockwell hardness HRA 80 or Vickers hardness Hv 1000.

In contrast, in Comparative examples 1 and 2, the cutting edge wore out greatly. As a result, the wear-out shape of the cutting edge adversely affected the shape error and the surface roughness.

Further, in Comparative example 3, the cutting edge got chipped, and in Comparative example 4, the cutting edge was broken. As a result, a die surface capable of transferring a proper optical surface was not formed.

Consequently, since none of the above references teaches a cutting technique to use a (110)-crystal face of the diamond as a rake face with a cutting-in depth of 1 μm or less in order to form a small curved die surface on the above super hard material, the above effect of the cutting technique of the present invention would have been unexpected from the above references.

9. I further declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001, of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Date: July 1, 2009

A handwritten signature in cursive script, appearing to read "Shigel Hosoe".

Shigel HOSOE

Fig. 1

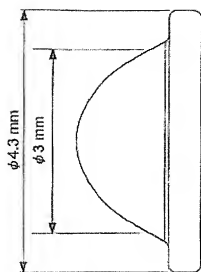


Fig. 2

